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Citation: AIP Conference Proceedings **1825**, 020006 (2017); doi: 10.1063/1.4978975

View online: http://dx.doi.org/10.1063/1.4978975

View Table of Contents: http://aip.scitation.org/toc/apc/1825/1

Published by the American Institute of Physics

Effects of Human and Mosquito Migrations on the Dynamical Behavior of the Spread of Malaria

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Abstract. Malaria is one of infectious diseases which become the main public health problem especially in Indonesia. Mathematically, the spread of malaria can be modeled to predict the outbreak of the disease. This research studies about mathematical model of the spread of malaria which takes into consideration the migration of human and mosquito populations. By determining basic reproduction number of the model, we analyze effects of migration parameter with respect to the reduction of malaria outbreak. Sensitivity analysis of basic reproduction number shows that mosquito migration has greater effect in reducing the outbreak of malaria compared with human migration. Basic reproduction number of the model is monotonically decreasing as mosquito migration increasing. We then confirm the analytic result by doing numerical simulation. The results show that migrations in human and mosquito populations have big influences in eliminating and eradicating the disease from the system.

INTRODUCTION

Currently there are many kinds of infectious diseases in the world. It can be spread through a variety of media such as air, water, direct contact or by insects including mosquitoes [14]. One of the classic infectious diseases is malaria. It is transmitted through the bite of a female Anopheles mosquitoes [7]. Parasites genus Plasmodium that enter to the human body through the bite will result in malaria-infected [3, 4, 12]. These types of parasite are Plasmodium Vivax, Plasmodium falciparum, Plasmodium ovale, and Plasmodium malaria [3,11]. Based on years of inoculation of sporozoites, plasmodium in humans is usually first detected at 7-14 days. The clinical symptoms such as sweating, pain, and fever will be visible a few days after the bite [2].

Malaria threatens 40% of human life on earth. These diseases affect the social, economic and health problem for countries in the tropics. Although research has been carried out against this disease for hundreds of years, malaria remains a major health problem. In 2008 there were 109 countries declared as endemic malaria [3, 11]. There are also 300 million clinical cases each year that were recorded as the incidence of malaria in the world. In addition, estimated at more than 2 billion people are at risk of malaria infection [2, 12]. The victim died due to malaria worldwide is more than 1 million people each year [7, 2, 12, 12]. The amount is potentially increase significantly related to the incidence of climate change [16].

Understanding the dynamics of disease transmission would help in the handling in the population [14]. Recently designed mathematical model to study the dynamics behavior of infectious diseases, including malaria, has been carried out to quantify the impact of infection disease in humans [1, 2, 3, 5, 6, 13, 9, 10, 11, 14]. The generated models involved many critical factors that directly influence the spread of the disease. In this research, we also study the dynamical behavior of malaria using mathematical model of Agusto et. al. [2]. We extend the model by taking into consideration migration in both human and mosquito populations. Migration is an important feature in the spread of malaria since it becomes one of mobility patterns that can cause infection of malaria [8, 11, 15].

We organize the paper as follow. In Section 2, we present model formulation of malaria by considering migration factors. In Section 3, we derive the steady-state solutions of the model, and we generate the basic reproduction number

Symposium on Biomathematics (SYMOMATH 2016)
AIP Conf. Proc. 1825, 020006-1–020006-8; doi: 10.1063/1.4978975
Published by AIP Publishing. 978-0-7354-1493-8/$30.00